

The IEEE Grid Interconnections Standard: How Will it Affect Wind Power?

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THE IEEE GRID INTERCONNECTION STANDARD: HOW WILL IT AFFECT WIND POWER?

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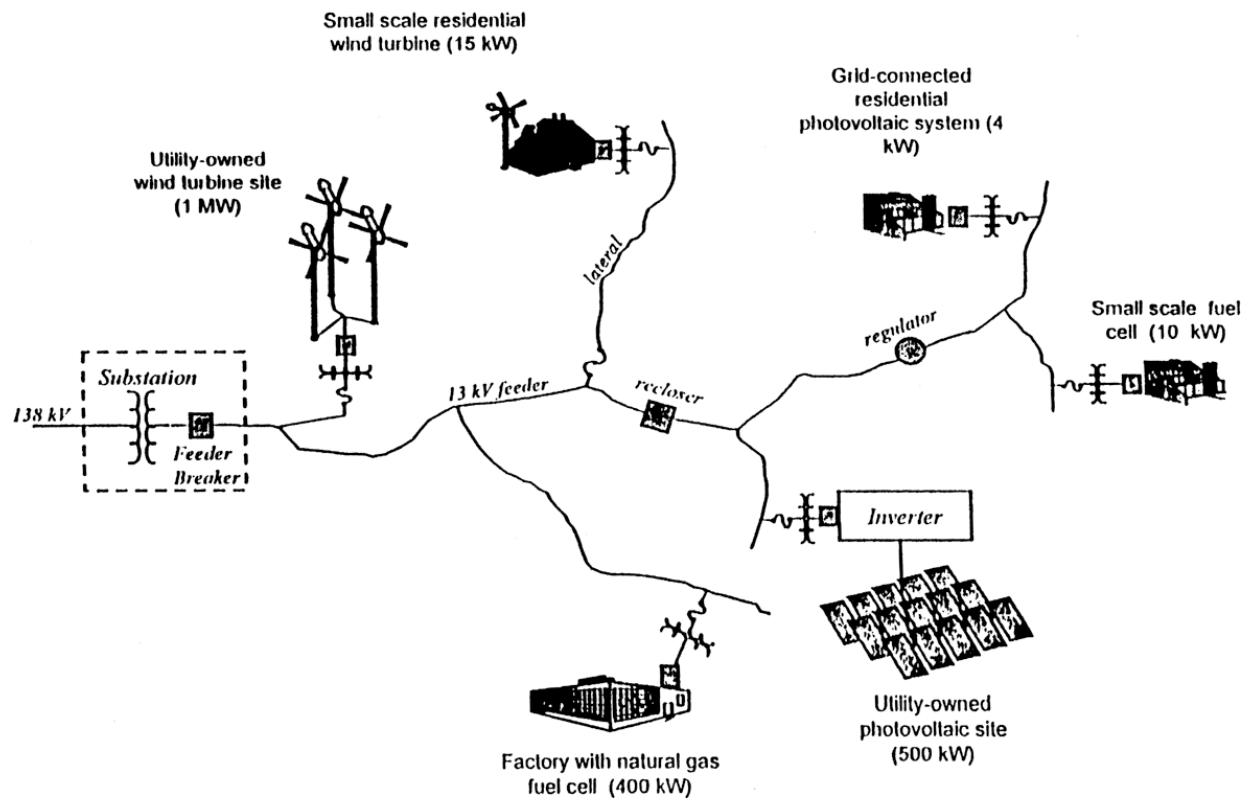
Abstract

In December 1998, the Institute of Electrical and Electronic Engineers (IEEE) began writing a standard for the interconnection of distributed resources with electric power systems. This standard will prescribe technical requirements for the interconnection of distributed resources that are connected to primary or secondary voltages in electric distribution systems. It is expected to play a significant role in facilitating a new, emerging market for small, distributed, primarily gas-fired, electric generators, including new technologies such as fuel cells and micro-turbines. Once published, this new standard will be enforced for the interconnection of distributed wind power applications, as well. The co-authors of this paper have been active with this standard from the beginning, focusing on issues most likely to affect interconnection of wind power. This paper describes the standard-writing process and highlights technical issues critical to wind power, with the intent of soliciting feedback from and encouraging broader participation by the wind industry.

Background

Prior to the passage of the Public Utility Regulatory Policies Act (PURPA) 1978, electric generators interconnected to distribution feeders were quite rare. PURPA opened the door for non-utility generators to connect to the utility grid and to sell or self-generate electric power. Now that door may become a floodgate with the emergence of new, small-scale electric generation technologies such as fuel cells and micro-turbines, as well as broader use of gas-fired reciprocating engine generator sets and turbines. Grid-connected photovoltaic (PV) and small wind generators continue to be used in larger numbers. Utility-scale wind turbines connected to distribution feeders, long common in Europe, have now begun to appear in the United States, as well. There is a growing expectation that the utility of the future may have a new look (see Figure 1).

Utility distribution systems today are typically designed for one-way flow of electric power from large, central generating plants to electric customers. This vision of the future in which bi-directional flow of power is possible raises utility concerns for the safety of utility personnel and for grid regulation, stability, and protection. Customers have concerns, as well. They want interconnection requirements that are not overly complicated or time consuming, and that have a reasonable cost for compliance. Manufacturers need broad standardization of interconnection requirements so they can develop and manufacture standard designs of equipment and software.



Source: Electric Power Research Institute (EPRI) Report TR11489

FIGURE 1. THE ANTICIPATED UTILITY OF THE FUTURE WITH A VARIETY OF SMALL GENERATORS CONNECTED TO A DISTRIBUTION FEEDER

Consequently, grid interconnection of distributed resources is getting a lot of attention. Fuel cell and micro-turbine manufacturers are actively promoting and encouraging the development of uniform national standards. Investor-owned utilities under the umbrella of the Edison Electric Institute are studying technical issues with interconnection. Individual states are addressing interconnection requirements, most notably New York, Texas, and California. In this environment, there was strong interest in developing a single standard with sufficient scope and credibility to be a uniform national interconnection standard. That effort is now under way within the IEEE.

Interconnection Standard Development

The interconnection standard is being developed by the P1547 Working Group within Standards Coordinating Committee 21 (SCC21) of the IEEE. SCC21 is responsible for standards development in the areas of fuel cells, PV, dispersed generation, and energy storage. The standard is being developed through a voluntary, consensus process, which is the hallmark of the IEEE approach to standards.

The new interconnection standard has been given the following title and purpose:

Title: Standard for Interconnecting Distributed Resources with Electric Power Systems

Purpose: Provide a uniform standard for interconnection of distributed resources with electric power systems, and requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection

The scope of the standard is limited to the interconnection of distributed resources to primary or secondary voltages in electric distribution systems. It will not cover DR that is interconnected to transmission lines. To date, no specific capacity limit has been stated in the standard, but around 10 MW is probably a practical limit to the size of DR which can be interconnected to a distribution system.

The standard has the following major sections:

- 1.0 Overview
- 2.0 Methodology for Classification of Interconnection Requirements
- 3.0 Interconnection Technical Specifications and Requirements
- 4.0 Test Specifications and Requirements
- 5.0 Summary of Interconnection Requirements

The key leadership positions in P1547 are:

- Richard DeBlasio, Chair, NREL
- Frank Goodman, Vice Chair, EPRI
- Joe Koepfinger, Vice Chair, Duquesne Light
- Tom Basso, Secretary, NREL

P1547 has well over 200 members. The typical Working Group meeting attracts between 70 and 80 participants, including a broad representation of utilities and manufacturers/producers, as well as general-interest participants. The work is on a fast track, with publication of the standard targeted for December 2001—just three years after starting. (See Figure 2 at the end of this paper.) This stands in contrast to the typical standard development cycle, which may run between five and eight years. The combination of unprecedented levels of participation, an aggressive schedule, and far-reaching technical content make this standard a truly remarkable endeavor.

Information about P1547 is posted on the Web at <http://grouper.ieee.org/groups/scc21/1547>. Working drafts of the standard are posted on this Web site, but are password-protected for the use of P1547 members only. Those who wish to join P1547 and participate in the standard-writing process should notify the P1547 Secretary, Tom Basso, by e-mail: thomas_basso@nrel.gov.

The IEC TC88 US TAG (Technical Advisory Group) for Wind has been invited by the IEEE to distribute, review, and comment on the draft standard. The TAG coordinators, John Dunlop (AWEA) and Sandy Butterfield (NREL), have accepted this invitation. The authors of this paper plan to continue to be involved in the P1547 Working Group meetings. We invite others in the wind industry to also be involved, either through participation in the working group or through review of drafts of the standard.

Grid Interconnection of Wind Power

As the P1547 process got under way in late 1998, the NREL National Wind Technology Center considered the question: “What are the current needs for interconnection standards for wind power?” The summary conclusions, shown in Table 1, were that standards were needed for small and medium-size wind installations. The other prominent fact was that the United States wind community has made a significant investment in the International Electrotechnical Commission (IEC) standards process. Any new interconnection standards should be consistent with, or at least not contradictory of, existing IEC standards for wind turbines.

Small wind turbines—nominally as much as 100 kW in capacity—interconnected at service voltages typically deliver power either through induction generators or inverters. A uniform interconnection standard is needed that covers both conversion technologies. A review of ANSI/IEEE 1021-1988, “IEEE Recommended Practice for Utility Interconnection of Small Wind Energy Conversion Systems” (now

withdrawn by the IEEE), found that it was primarily descriptive rather than prescriptive. Rather than providing technical requirements, it left them up to the host utility. Also, although IEEE 929-1988 (R1991) “IEEE Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic Systems” provides comprehensive guidance for grid-interconnected inverters, it is limited to 10 kW in size and is written specifically for PV systems. (Even so, this document is being used by the State of California for grid-interconnection of net-metering small wind turbines.)

Utility-scale wind turbines connected to distribution feeders were not prevalent in the United States in 1998. However, such applications were already typical in the wind industry in Europe. To encourage these applications in the United States, it was clear that a uniform standard was needed to provide utilities with confidence on issues such as power quality and protection and, hopefully, to limit the cost of grid interconnection for wind energy developers.

As for large wind farms, there did not appear to be a need for interconnection standards. Wind farms typically are connected to transmission lines through dedicated substations. There are existing IEEE and utility standards addressing relaying and protection for substation design. Overall, grid interconnection has not been a market impediment to wind power development in California. (We are not speaking here about transmission access or transmission capacity, which have been problems in some cases.)

TABLE 1. CURRENT NEEDS FOR GRID
INTERCONNECTION STANDARDS FOR WIND POWER

Power Conversion Technology	Interconnection Voltage		
	Service (up to 100 kW)	Distribution (up to 6 MW)	Transmission (up to 110 MW)
Induction Generator - Single-speed, 2-speed, soft start, PF capacitors	✓	✓	✓
Synchronous Generator		✓	✓
Inverter	✓	✓	✓
Doubly-Fed Induction Generator		✓	✓
Interconnection Standard Needed?	Yes	Yes	No

Interconnection Technical Issues

Many technical issues pertinent to these large wind turbines are at stake in this standards process. For larger wind turbines, these include limits on voltage flicker, compatibility with feeder circuit-protection devices, quickly tripping off at the appropriate times, power quality impacts on the distribution system,

and possible requirements for periodic testing of protective relaying functions. Interconnection of residential-scale wind power will also be impacted. Critical issues for small wind turbines include non-islanding capability, limits on total harmonic distortion, and possible requirements for a visible, lockable disconnect.

There is a concern that distributed generation must trip off-line quickly when the substation feeder breaker opens to clear a fault on the distribution line. If the generation doesn't trip off before the feeder breaker recloses, then it could cause damage to the distributed generation in some cases. The length of time allowed for a wind turbine to detect the resulting loss of the grid and then trip off is short; it may be an issue for some types of large wind turbines. There is also a concern that if the substation feeder breaker opens with no fault on the line, then the distributed generation must also trip off to avoid creating an "island" served by the distributed generation. This could possibly require some protective relaying functions to be added to wind turbines that are connected to distribution feeders. Generally, a wind turbine would trip off line if the substation breaker opens, but it is possible that it might not trip within a few seconds.

Large wind turbines have the potential to cause voltage fluctuations on relatively weak distribution systems that could cause light flicker. To avoid having this type of power quality problem, the flicker levels must be predicted before a wind turbine is connected to a distribution line. P1547 will attempt to adopt a minimum standard for any type of distributed generation. Because the IEC has a comprehensive standard describing flicker limits, the authors have proposed that it be used in the new IEEE standard. The IEC is also developing a standard for power quality for grid-connected wind generation that is much more comprehensive than that being considered by P1547. Therefore, there is a need to ensure that P1547 is somewhat compatible with the IEC standards.

In the past, additional protective relays have been required by utilities when wind turbines were connected to customer's services or to distribution lines. P1547 will prescribe the relaying functions that are required, rather than the specific relays. Many of these functions are already built into modern wind turbine controllers. A potential issue for the wind industry is the testing and verification of these built-in protective functions. For example, how does a wind turbine operator know that a specific wind turbine will correctly trip offline if the frequency or voltage exceeds the set points programmed into the controller? The utility industry wants a method to ensure that the protective relaying functions work as they are designed. This would require changes in the wind turbine controllers that would allow the functions and settings to be verified and tested periodically. Third-party "type" testing of specific controller designs is being discussed as an alternative to in situ testing.

The section on synchronization with the grid might include a limit on voltage fluctuations for across-the-line starts of induction generators. Use of soft-start power electronics will be recommended. Use of the prime mover (e.g., the wind turbine rotor) to bring the induction generator to synchronous speed before energizing the generator is also permitted.

Most small wind turbines today operate variable-speed and are grid connected through a static inverter. Inverters are being treated in P1547 in the same manner that has recently been recommended by the IEEE for grid-connected photovoltaic systems in IEEE 929-2000, "IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems." This document includes a requirement that the inverters be "non-islanding." Methods by which an inverter will sense a grid outage and cease to operate are clearly defined along with the test protocol, UL (Underwriters Laboratory) 1741, by which this functionality is to be tested. Limitations for harmonic distortion given in IEEE 519, "IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems," will also be incorporated into P1547. The requirement for a visible, lockable disconnect available to utility personnel is still an open issue in the

current draft. This requirement is common practice, but does add cost, particularly to residential-scale systems. And, it is a requirement that is redundant with the non-islanding capability noted above.

There will be other requirements in P1547; however, most will not prove to be barriers to wind generation being interconnected to the distribution system.

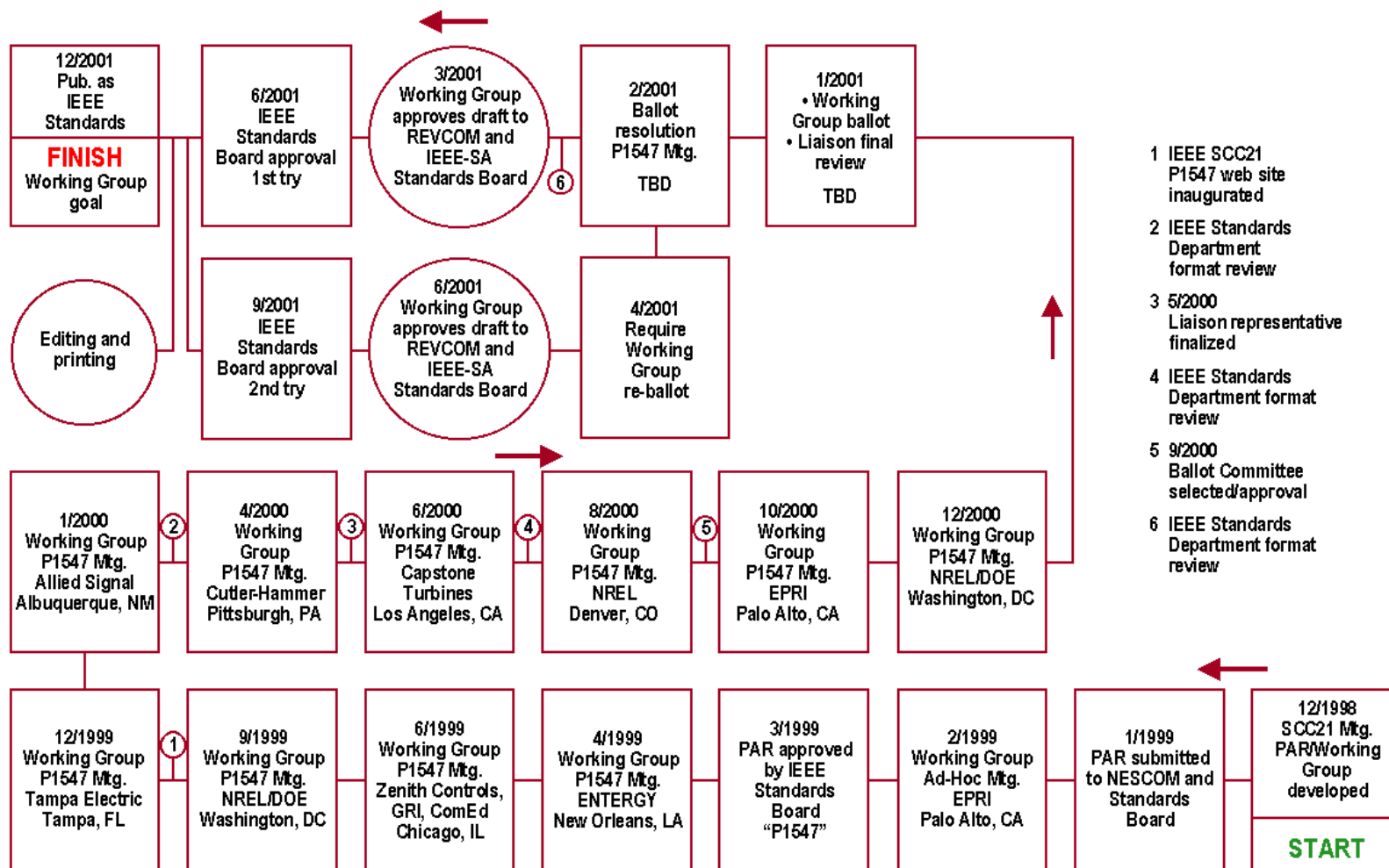
Conclusions

The development of a new IEEE standard, P1547, for the grid interconnection of distributed resources is progressing rapidly, with publication targeted for the end of 2001. We strongly encourage the wind industry to follow the development of this standard more closely and to offer review comments on the working drafts as they become available. The actual writing of the standard should be completed by December 2000. So the coming three to six months will be the best opportunity for the wind industry to influence the content of this document—a standard we should expect to live with for some time to come.

In its current form, it appears that this new standard will be largely compatible with current practice for grid interconnection of both utility-scale and small wind turbines. To the extent that it becomes a widely accepted and enforced standard in the years to come, it should facilitate wider use of wind power on distribution feeders by providing uniform technical requirements, by reducing the cost of interconnection hardware, and by reducing the time and expense associated with getting an interconnection agreement with the host utility.

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FIGURE 2. PROPOSED TIMELINE FOR IEEE SCC21 STANDARDS DEVELOPMENT PROJECT P1547